AN IMPROVED SPECTRAL CALIBRATION REQUIREMENT FOR AVIRIS

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1. IN'J'I{ODIJC'1'1ON

The Airborne Visible/Infrared imaging Spectrometer (AVIRIS) measures spectra from 400 to 2500 nm through 224 contiguous spectral channels. These spectra arc used to identify and determine the abundances of constituents of the Earth's surface and atmosphere through the analysis of spectral molecular absorption and scatt ering properties of materials. Spectral calibration of the AV1 RIS is required to pursue these determinations, which are based on these fundamental spectral characteristics.

The spectral calibration of AVIRIS consists of a description of the spectral response function for cacb of the 224 spectral channels. The spectral response function of AVIRIS channels was measured in the laboratory and shown to be Gaussian in shape (Chrien et al. 1990). Figure 1 shows a subset of nine AVIRIS spectral channels with channel centers at 10 nm intervals and channel shapes of Gaussian form with 10 nm full width and half maximum (FWHM). For AVIRIS the spectral calibration is described by the spectral center and FWHM of a Gaussian function for each channel. Uncertainty in the determination of the spectral center and FWHM for each channel arc also reported.

This paper presents results from an investigation of the sensitivity ofAV11<1 S measurements of the upwelling radiance to errors in spectral calibration. Based on this sensitivity analysis in conjunction with earlier work (Green et al,, 1990), an improved spectral calibration requirement for AVIRIS is proposed.

2. AVIRIS MEASURED RADIANCE

AVIRIS measures the upwelling spectral radiance from the sun that was reflected by the surface as well as absorbed and scattered by the intervening atmosphere. To investigate the effect of spectral cal ibrat ion on measurement of the upwelling radiance, a high resolution spectrum of the radiance arriving at

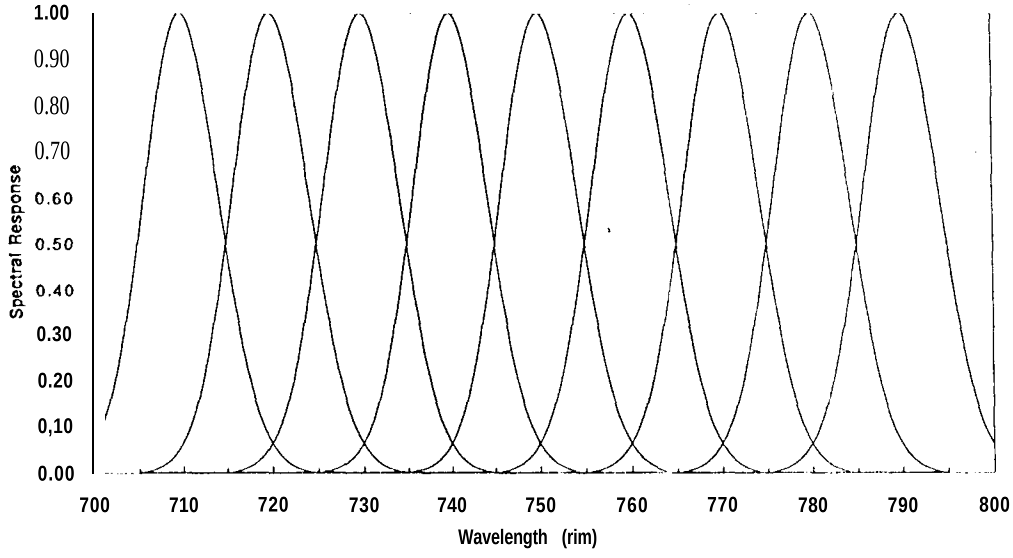

Figure 1. Modeled spectral response functions of 9 AVIRIS channels,

AVIRIS was generated by the **MODIRAN** radiative transfer code (Berk, et al. 1989). Figure 2 shows the modeled upwelling radiance arriving at AVIRIS at 2 wave-number' spectral resolution with a 0.25 reflectance surface, 45 degree solar zenith angle, and the mid-latitude summer atmospheric model. Across this spectral range, the upwelling radiance is dominated by narrow atmospheric and solar absorptions as indicated on the figure.

The radiance reported by each AVIRIS channel is the result of the convolution of the upwelling spectral radiance with the spectral response function of each channel. This spectral convolution is given in equation 1. For each spectral channel, the measured radiance L_i is the product of the channel spectral response function $f(\lambda_i - \lambda)$ and the upwelling spectral radiance $L(\lambda)$ at each wavelength elk:

$$L_i = \int f(\lambda_i - \lambda) * L(\lambda) d\lambda \tag{1}$$

In Figure 3, the AVIRIS radiance convolved through 10 nm FWHM Gaussian spectral channels is given. Because the upwelling spectral radiance contains numerous narrow solar and atmospheric

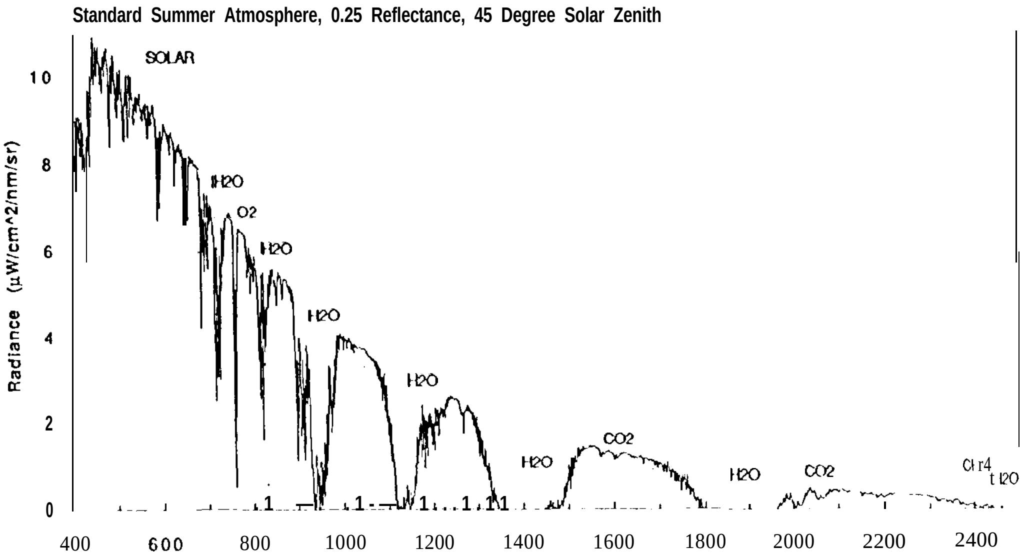

Figure 2. MODTRAN radiative transfer code modeled upwelling spectral radiance.

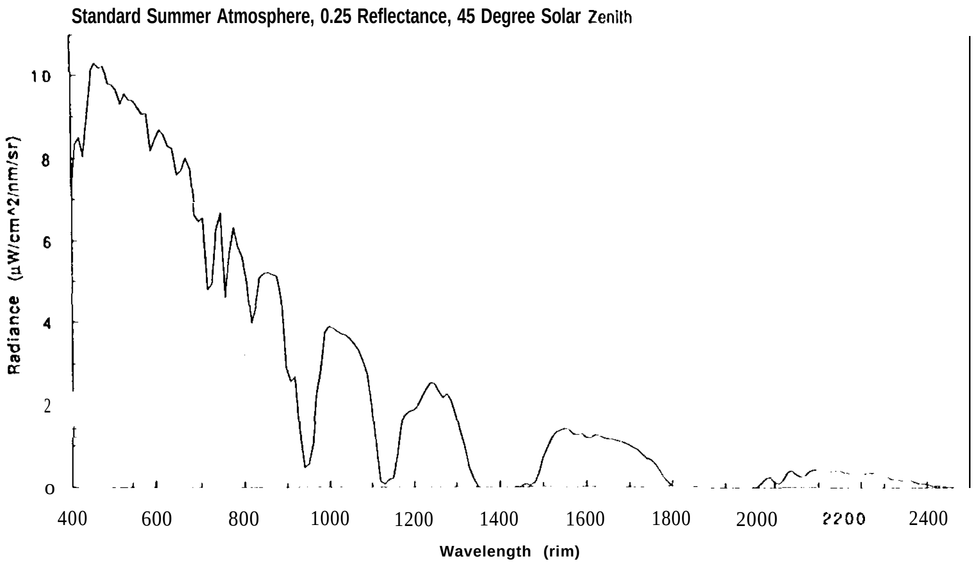

Figure 3. Result of the convolution of the MODTRAN radiance spectrum by the AVIRIS spectral channels.

absorption, the spectrum in Figure 3 is strongly dependent on the spectral position and FWHM of each of the AVIRIS channels.

3. AVIRIS SPECTRAL CALIBRATION SENSITIVITY ANALYSIS

To understand the sensitivity of the AVIRIS measured radiance to the spectral calibration, a sensitivity analysis was performed. For this analysis, errors in both channel center and FWHM were evaluated. The effects of error in channel center position were investigated by introducing a systematic spectral shift across the spectral range. For FWHM investigation, errors of systematic broadening were introduced. Sensitivity to these spectral calibration errors was assessed as the percent difference in radiance measured through a spectral channel with and without the spectral calibration error.

Sensitivity in calibration of the channel center position was tested by calculating the convolved radiance for shifts in spectral channel positions of 1.0, 0.5, and 0.1 nm. These errors correspond to 10, 5, and 1 percent of the nominal 10 nm AVIRIS spectral resolution. The percent difference in radiance between the error free and spectrally shifted spectra is shown in Figured. Spectrally distinct errors throughout the spectral range increase as the errors in calibration of the spectral channel center position grow. For example, at 930 nm, an error of 1.0 nm in channel position caused a - 15 percent error in measured radiance. At 930 nm, a 0.5 nm shift caused a -8 percent error in radiance and a 0.1 nm shift caused a -1.5 percent error.

An analysis of the sensitivity of channel FWHM calibration was performed through calculation of the percent error in radiance for errors in the spectral FWHM of 1.0, 0.5, and 0.1 nm. These results are shown in Figure 5. As with errors in channel position, errors in the calibration of channel shape cause errors in the sensor measured radiance. At 1120 nm, errors in channel width calibration of 1.0 nm, 0.5 nm, and 0.1 nm result in radiance errors of 11.3, 5.6, and 1.1 percent, respectively.

Spectral calibration errors of a given percentage of the spectral resolution are shown to cause errors of a greater percentage in measured radiance in spectral regions with strong narrow absorption in the upwelling radiance. Errors in the measured radiance directly propagate to calculations of apparent reflectance. Spectral calibration induced errors in measured radiance impact algorithms that use spectral fitting to known reference spectra as well as algorithms that derive parameters from spectral models. Furthermore, the spectrally sharp nature of these errors mimics and modifies actual molecular absorption and consequently undermines the general spectral measurement objectives of imaging spectrometry.

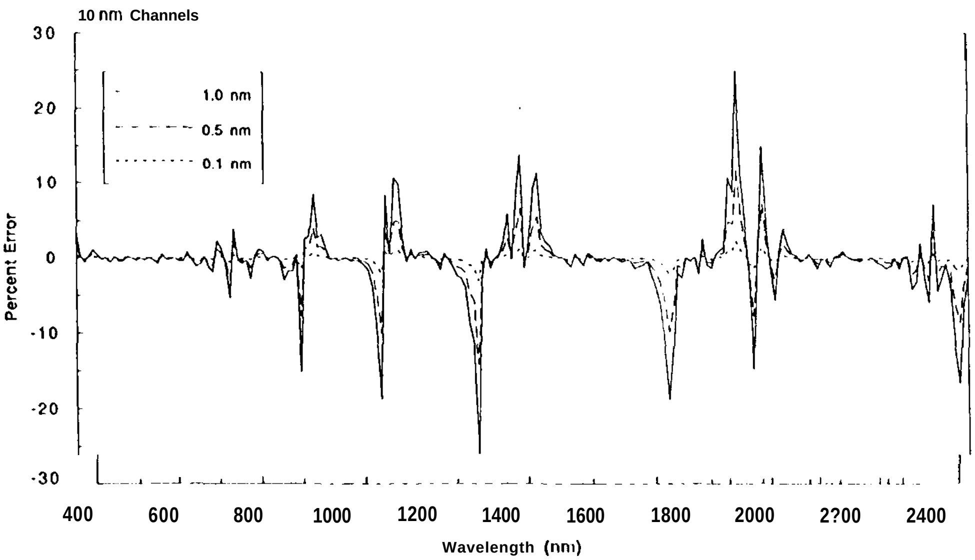

Figure 4. Error in AVIRIS modeled upwelling radiance with errors of 1.0, 0.5 and 0.1 nm errors in the calibration of channel center position.

4. CONCLUSION

These sensitivity analyses show that the ubiquitous narrow solar and atmospheric absorption in the upwelling spectral radiance drive the requirement for spectral calibration of AVIRIS. The original spectral calibration requirement for AVIRIS was ±5.0 nm for spectral position and FWHM. Based on these analyses, a spectral calibration requirement of 5 percent (0.5 nm) and goal of 1 percent (0.1 nm) of the spectral resolution arc justified to provide AVIRIS spectra that arc free of significant spectral calibration induced errors.

5. ACKNOWLEDGMENTS

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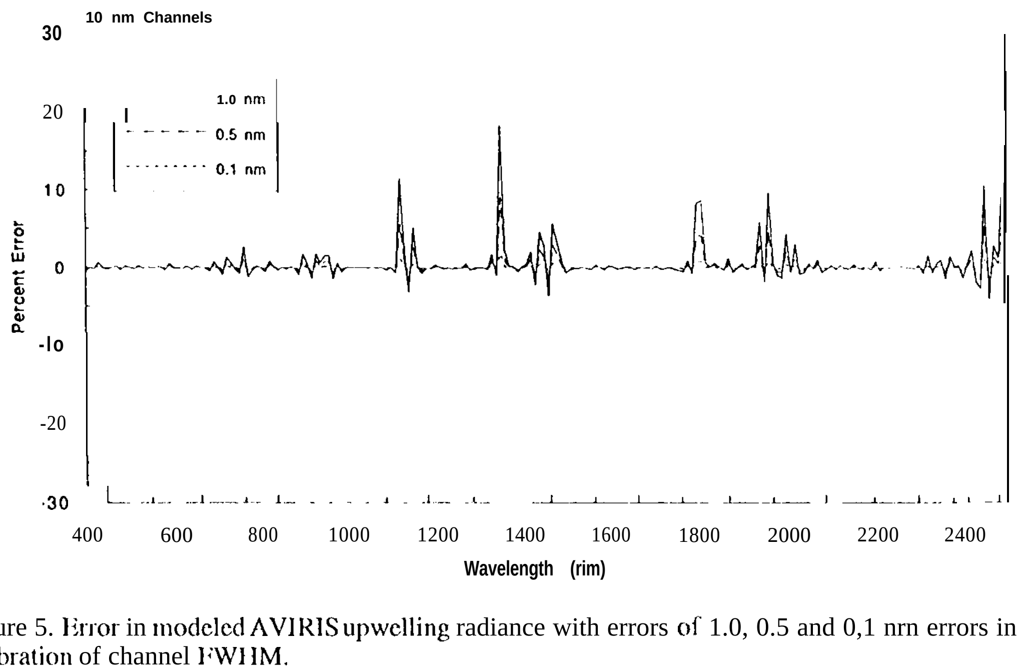

Figure 5. Error in modeled AVIRIS upwelling radiance with errors of 1.0, 0.5 and 0,1 nrn errors in the calibration of channel FWHM.